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DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
HUGH M. SMITH, Commissioner

THE MUSSEL FAUNA OF CENTRAL AND NORTHERN MINNESOTA

By CHARLES B. WILSON and ERNEST DANGLADE

APPENDIX V TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1913

Bureau of Fisheries Document No. 803

WASHINGTON
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THE MUSSEL FAUNA OF CENTRAL AND NORTHERN MINNESOTA.

By CHARLES B. WILSON and ERNEST DANGLADE.

INTRODUCTION.

As a part of the fresh-water mussel investigations conducted by the Bureau of Fisheries, the central and northern portions of Minnesota were examined during the summer of 1912 with regard to the kinds and numbers of mussels to be found in the lakes and rivers. The mussel fauna of the Mississippi River in Minnesota below St. Paul and of the Minnesota River have been thoroughly investigated by representatives of the various pearl-button companies, and the quality and amount of shells which they produce have become fairly well known. The central and northern portions of the State had never been examined except by mussel fishermen. The shells obtained by some of these fishermen, however, and shipped to the button factories were of such exceptional quality as to attract the attention not only of the manufacturers but also of the Government experts at the biological laboratory at Fairport, Iowa. Since some of these shells were obtained from lakes and others from rivers, it was determined to make a preliminary survey of both lakes and rivers through the central and northern portions of the State.

This survey had a threefold object: First, to determine the geographic distribution of the various mussels in those portions of the State. Incidentally, of course, this would answer the question whether the exceptionally fine shells were locally or generally distributed, and where they were to be found.

Second, to make as careful a survey as possible of the various conditions, conducive or adverse to mussel development, in the different localities visited. This would not only throw some light on the presence of exceptional mussels in certain localities, but would also serve as a basis for the final object of the survey.

Third, to ascertain whether it would be profitable to introduce artificial propagation in any of the lakes or rivers, and if so, what species would be best adapted to the locality.

The investigating party consisted of the two authors, and in consequence of the large territory to be covered and the isolation of many of the localities visited it was necessary to travel entirely by rail-

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road, stopping at convenient centers and driving to the lake or river. During this trip 45 lakes and 15 rivers were examined, with the results as herein given.

Samples of the shells obtained by the authors at the different localities herein mentioned have been identified by Mr. H. Walton Clark, of the biological station at Fairport, Iowa. Similar samples have been tested as to their mercantile value by Mr. John Southall, of the same station.

In order to understand the geographic distribution of the mussels, it is necessary to review so much of the glacial geology as will explain the present location of the lakes and rivers as well as their former relations.

GLACIAL ORIGIN OF LAKES AND RIVERS.

Minnesota was formerly covered by a great glacier or ice sheet, which came down from the northeast and flowed across the State into Iowa. When the glacier melted, the gravel, sand, and clay which it carried was spread out over the surface of the underlying rocks and has remained there ever since. The only exception is a narrow strip bordering the Mississippi River from Lake Pepin southward, and thus outside of the present survey. North of Lake Superior this drift, as it is called, is thin in places, but elsewhere it averages from 100 to 150 feet in thickness and effectually conceals the bedrock.

Both glacier and drift have made the contour of the State more level and uniform than it was before. The glacier accomplished this by grinding off the ridges and elevations, while the drift assisted by filling in such hollows as were left by the glacier. In some places the material of the drift has been subsequently worked over and arranged in layers by the streams and rivers that flowed from beneath the glacier, but in most places it is still unstratified. During the melting of this great glacier there were successive periods of advancing, halting, and retreating, and at such times the drift accumulated in long hills or ridges called moraines, parallel with the edge of the glacier. Twelve of these moraines may be traced across the State in various directions, and while they are only from 25 to 75 feet in height, they are still sufficient to determine the general drainage of the State. They have the further effect of rendering any free drainage impossible, and thus they give rise to the remarkable number of lakes that are found in Douglas, Ottertail, Itasca, and other counties. Furthermore, the streams and rivers are very winding, and have a uniform current, and there are plenty of sand and gravel beds in the bottom of the lakes and rivers, and not very much mud. All these conditions are favorable for mussel growth and propagation and profoundly influence the mussel fauna.

When the melting ice sheet had receded beyond the moraine or watershed which separated the basin of the Minnesota River from

that of the Red River of the North, a large lake, called Lake Agassiz, was formed along the edge of the ice. As the ice withdrew, this lake extended northward along the Red River Valley as far as what is now Lake Winnipeg. Lake Agassiz was 700 miles long and covered 110,000 square miles, and its duration is estimated to have been about a thousand years. Its outlet, known as the glacial river Warren, was along the valley now occupied by Lakes Traverse and Big Stone and the Minnesota River, into the Mississippi. At that period, therefore, the Mississippi River may be said to have had its origin in Lake Agassiz. And during the thousand years of its existence, this lake had abundant opportunity to become populated with fresh-water mussels ascending from the Mississippi. The lake disappeared, however, and the valley of the Minnesota River separated from that of the Red River. But the mussel faunas of the two rivers were derived from identically the same source, and the only differences would be the few minor changes that have crept in since then.

Many other glacial lakes were formed during the melting of the ice sheet, only to be subsequently obliterated. But while they existed they served as temporary channels for the migration of fish and mussels from the south. Two of these are of especial interest, in view of the results of our present investigation. Lake Upham once covered the region south of the Mesabi Iron Range, and drained southeast along the valley now occupied by the St. Louis and Cloquet Rivers. This lake was very shallow and temporary and, as far as can be determined, was not connected with the Mississippi River in any way. This fact accounts for the paucity of mussels in that portion of the State, as well as in all the Lake Superior drainage.

Lake Nicollet was formed around the headwaters of the Mississippi River and covered an area of 1,500 square miles. It drained southwest into the valley now occupied by the Crow Wing River and thence into the Mississippi. The Crow Wing River thus becomes the modern representative of the old headwaters of the Mississippi, and is older than that portion of the latter river which now extends from the mouth of the Crow Wing up to Lake Itasca. These facts explain the richness of the mussel fauna in the Crow Wing and its tributaries. At two places in the area covered by the present survey the bed rocks appear above the drift with sufficient prominence to materially affect the mussel distribution. At Carlton the St. Louis River plunges over a rocky ledge and through a gorge, which prevents the passage of either fish or mussels. Consequently that portion of the Lake Superior drainage which is tributary to the St. Louis River above Carlton is devoid of mussels.

The Falls of St. Anthony at Minneapolis have formed a similar barrier in the Mississippi River, but with this difference: Some fish have evidently been able to ascend these falls while others could not accomplish it. Accordingly, we find in the Mississippi above the falls, and in its tributaries an abundance of mussels belonging to the *Lampsilis* or mucket group, plenty of *Anodonta*, *Symphynota*, *Strophitus*, and the like, but not a solitary specimen was seen of the great *Quadrula* or pig-toe group. The falls have manifestly furnished in some way an effective barrier to the distribution of these mussels. On the other hand, the Minnesota River enters the Mississippi some distance below the falls, and it contains as many pig-toes as muckets.

The pig-toes also ascended the glacial river Warren into Lake Agassiz, and we find them to-day in the Red River of the North. They also ascended the St. Croix River, and in the St. Croix drainage they are even more numerous in species than the muckets.

For convenience we may divide the lakes and rivers which were examined into five groups, and designate them, respectively, the St. Croix group, the Minnesota River group, the Red River group, the Crow Wing group, the Mississippi River group, and the isolated lakes.

MUSSELS OF THE ST. CROIX GROUP.

The lakes and rivers in this eastern central portion of Minnesota have been populated with mussels by way of the St. Croix River. This connection was established after the melting of the glacier and has not been materially changed since that period.

Joining the Mississippi some distance below St. Paul, and having no falls or other natural obstruction in its own course, the St. Croix River has afforded a constant and easy passage for all the Mississippi species of fish and mussels. Hence we find a goodly variety of both in the lakes and rivers belonging to the St. Croix drainage. The following table gives the geographic distribution of the various mussels found here during the present survey:

DISTRIBUTION OF MUSSELS IN ST. CROIX DRAINAGE.

Species.	Pokegama Lake.	Snake River.	Cross Lake.	Rush Lake.	Bald Eagle Lake.	White Bear Lake.	Forest Lake.
Lampsilis luteola (fat mucket)	×	×	×				×
Lampsilis ventricosa (pocketbook)	×	×	×				
Lampsilis recta (black sand-shell)		×	×				
Lampsilis alata (pink heel-splitter)		×	×				
Symphynota complanata (white heel-splitter)			×				
Strophitus edentulus (squaw-foot)	×						
Anodonta corpulenta (floater)	×		×	×	×	×	×
Quadrula undulata (blue-point)	×	×					
Quadrula plicata (three-ridge)		×	×				
Quadrula undata (pig-toe)	×		×				
Quadrula lachrymosa (maple-leaf, stranger)	×	×	×				
Quadrula pustulosa (warty-back)	×	×					

No comment upon the fauna of the last four lakes is needed save the single statement that the muckets in Forest Lake are all dwarfed and thin-shelled. The other two lakes and Snake River are parts of the same system, for the river flows through the entire length of Pokegama Lake and across Cross Lake nearly at its center. Both of the lakes and the river are shallow, and consequently the mussels are gathered with a rake or by wading. No crowfoot dredges were seen.

QUALITY OF SHELLS.

The principal mussel here is the fat mucket, which is not dwarfed, as is usual in a lake, but retains its full size. Furthermore, the shell is exceptionally thick and heavy, and maintains this thickness to the extreme tips, making every portion of it available for buttons. The shells have a fine luster, show no discoloration, and will cut from 700 to 720 gross of blanks (20-line) to the ton. In Pokegama Lake these muckets form 75 to 85 per cent of the entire catch; in the Snake River between the two lakes, 60 per cent, and in Cross Lake from 40 to 50 per cent.

Of the other shells, the maple-leaves and blue-points are also exceptionally thick, of large size, unspotted, and in every way first-grade button shells. The three-ridges, on the contrary, are badly spotted, have a poor luster and are only second or third quality. The culls are nearly all heel-splitters and *Anodontas*. In Cross Lake the bottom is sandy next to the shore, and then becomes covered with mud, while in Pokegama Lake it is hard sand throughout. Hence there are more three-ridges, black sand-shells, blue-points, and floaters in Cross Lake, and the shells are not quite as thick as those in Pokegama Lake.

At the time these lakes were examined (July) there were fully two carloads of shells scattered along the shores of Cross Lake on the west side, and as many more at the upper end of Pokegama Lake, gathered within a space of 400 or 500 feet. The fishermen said they had been offered $23.50 per ton for these Pokegama shells.

PEARLS.

The best pearl found in this vicinity was obtained from a fat mucket in Cross Lake several years ago, and was held for some time at $4,000. The price then gradually dropped to $3,000, and it was finally sold for $2,300. Of those found in 1912 one brought $1,800, another $1,200, a third $900, two were sold for $500 each, and six or eight reached $100 or over. In consequence of these exceptional finds everyone in the neighborhood caught the pearl fever, and they were all—men, women, and children—fishing for pearls at the time of our visit, the mucket being the favorite shell for them. But they

showed far more wisdom than is common under such circumstances, for even the children had sense enough to save the valuable shells and turn them over to a local blank factory situated on the shore of Cross Lake in Pine City. At that time this factory was running entirely on such small job lots, which could be obtained at a considerable reduction in price.

PROPAGATION.

Some of the mussel fishermen claimed that this locality was practically worked out, and in consequence they had left and gone to Rice Lake. But all of those who remained told us that they had no difficulty in gathering 500 or 600 pounds a day. The supply, however, is not inexhaustible, and unless measures are taken to replenish the more valuable species they will soon be gone.

Everything combines to make this an ideal location for such artificial propagation. Pine City, the county seat of Pine County, is conveniently reached by the Northern Pacific Railroad, 60 miles from St. Paul. It is located on the shores of Cross Lake and along the banks of Snake River, and the waterway is unobstructed up the river into Pokegama Lake. Hence propagation at a single point would supply both of the lakes and the river. And there is an abundance of the right kind of fish to serve as hosts for the glochidia.

RECOMMENDATIONS.

1. The muckets and the maple-leaves that are found here are exceptionally fine shells, and in some way the local conditions are peculiarly suited to their development. They should be locally propagated, therefore, in sufficient numbers to keep up the supply. In all probability they will yield better returns than any other species that could be introduced.

2. A careful study of these mussels and of the local conditions should be undertaken in order to determine, if possible, what it is in the way of lime, food, or other things that renders these shells so exceptionally fine.

3. With a good local supply of these remarkable shells and a working knowledge of the conditions under which they flourish, it would be a simple matter to introduce them into other localities having a similar happy combination of river and lake. Among such possible localities may be mentioned Rice and Koronis Lakes near Paynesville in Stearns County, Clearwater Lake near Annandale in Wright County, Lost and West Lost Lakes near Fergus Falls, and Pine and Little Pine Lakes near Perham in Ottertail County.

4. A small local factory may often render efficient service by saving the odd lots of shells that are just as good in quality as any of

the others and perhaps even better, but are not sufficient in quantity to warrant shipping them for any distance. Such factories deserve the encouragement of both fishermen and manufacturers.

MUSSELS OF THE MINNESOTA RIVER GROUP.

As has been already stated, the Minnesota River and its tributaries have been pretty thoroughly worked up by representatives of the button factories. Like the St. Croix, this river empties into the Mississippi below the Falls of St. Anthony, and so affords a free passage for all kinds of fish and mussels. Furthermore, it formed a part of the glacial River Warren, which was the outlet of Lake Agassiz, and thus there has been no break in its connection with the Mississippi.

The present investigation did not include the river itself, but only some of the lakes in Douglas County that eventually drain into it by way of the Chippewa River.

Within a radius of 6 miles from Alexandria, the county seat of Douglas County, there are 20 small lakes, several of which have become quite noted summer resorts.

Lakes Agnes, Henry, and Winona are close to the railroad station, small, shallow, and filled with water plants. The only mussels found in them were dwarfed and thin-shelled muckets (*L. luteola*), whose epidermis was highly polished and somewhat marly and whose nacre was a beautiful smoky brown.

Four miles north of the city there is a group of three larger and much deeper lakes, called, respectively, Darling, Carlos, and L'Homme Dieu. These lakes are comparatively free from water weeds, have sand and gravel bottoms, are very deep, and contain plenty of fish, but the only mussels that could be found in them were *Anodontoides freussacianus modestus* and *Anodonta pepiniana*.

A similar fauna was reported for the other 14 lakes, so that it does not appear as if any of the lakes in Douglas County contained commercial shells. Nor do any of them present conditions that would recommend the introduction of merchantable species by means of artificial propagation.

Some of the isolated lakes in this drainage, however, present entirely different conditions.

MUSSELS OF THE RED RIVER GROUP.

The lakes and rivers belonging to this group were populated with mussels from the Mississippi River by way of the glacial river Warren and Lake Agassiz. Since the disappearance of this glacial river and lake the Minnesota River drainage and the Red River drainage have been separated, and each has acquired peculiarities of its own. The Red River turns northward along the western border of the

State and carries its mussel fauna across the line into Canada. It therefore becomes of great interest to the conchologist, as well as the mussel fisherman, since in it the mussels of the Mississippi Valley reach the point farthest north in their migrations. In consequence of the long continued glacial connection with the Mississippi, we are not surprised to find the rich mussel fauna indicated in the following table:

DISTRIBUTION OF MUSSELS IN RED RIVER GROUP.

Species.	Little Pine Lake outlet.	Red River at Perham.	Otter-tail Lake outlet.	West Lost Lake outlet.	Red River below Fergus Falls.
Anodonta pepiniana (paper-shell, floater)	×	×	×	×	
Anodontoides ferussacianus subcylindraceus			×		
Strophitus edentulus (squaw-foot)		×	×	×	
Symphynota costata (fluted-shell)	×	×	×		
Symphynota complanata katharinæ	×	×		×	
Lampsilis luteola (fat mucket)	×	×	×	×	×
Lampsilis ventricosa (pocketbook)	×	×	×		×
Lampsilis recta (black sand-shell)	×	×	×	×	×
Quadrula coccinea (round pig toe)			×		
Quadrula rubiginosa (Wabash pig toe)					×

The only place in this entire drainage that has ever been worked is just north of Fergus Falls, where some of the country boys gathered and shipped a carload of shells to the button factories in Iowa in 1910. All of the lakes and the river are shallow and the shells must be gathered with rakes or forks, or picked up by hand; there is no chance for crowfoot dredges.

QUALITY OF SHELLS.

The mucket, the pocketbook, and the fluted shell are the principal commercial mussels in the Red River. The black sand-shell is abundant and the best shell of them all in quality, but as it always has a dark purple nacre it can be used only for novelties. In many of these northern sand-shells, the hinge line, instead of being straight (*recta*), is strongly curved. But as it conforms in other particulars to a normal *recta*, it seems best to regard this merely as a local variation. The pocketbooks also are peculiar in being much flattened, somewhat elongated, and with short and stumpy teeth, very much like the variety designated by Lea as *Unio canadensis*. Many of the muckets have shells as thick and heavy as those of the St. Croix drainage, but there are others whose shells are thin and sometimes dwarfed like lake specimens.

The shells of nearly all the mussels which have a white nacre are badly stained. These stains vary from a light-gray or drab to a dark rusty brown in color. Sometimes there is but a small discoloration

on each valve, at other times the whole interior of the shell is discolored. The stain usually affects only the interior layer or coat of nacre and when this is removed the rest of the shell is perfectly clean and uninjured. Such spotting of the shell, of course, injures their commercial value and reduces the material to the second or third grade. In other respects the shells have a fine luster and good texture, and would make excellent button material.

PEARLS.

A few pearls and about the usual number of slugs were obtained from the carload of shells sent from Fergus Falls. At Little Pine Lake we also received reliable information that pearlers had worked the Red River above Mud Lake two years before, and that they obtained an abundance of mussels, with a fair amount of pearls. Further than this there has been no search for them in the Red River. If the discoloration noted above is due to some sort of parasite, it would very likely affect the pearls and slugs as well as the shells, but no data could be obtained. There is no reason other than this why the Red River should not be as prolific of pearls as the Mississippi.

PROPAGATION.

The conditions at Ottertail Lake are very favorable for the propagation of certain species of mussels. The lake is 10 miles long by 4 miles wide, and is remarkably clean and free from weeds. It is surrounded also with fine sand and gravel beaches and contains many large sand bars. The Red River enters at the northeastern corner and flows the entire length of the lake. Similar conditions exist at Lost, West Lost, Pine, and Little Pine Lakes, but the lakes themselves are much smaller. At little Pine Lake the bottom was nearly covered with *Chara* and algæ, but wherever there was a bare spot the mussels were present in large numbers. As these lakes are full of just the kind of fish to serve as hosts the conditions are ideal for mussel propagation. On the river itself the conditions are less favorable. There are several dams in Fergus Falls, and a large power dam, 36 feet in height, 4 miles below the city. None of these dams are provided with suitable fishways, so that they form an effective barrier to the ascent of all fish.

RECOMMENDATIONS.

1. Evidently the first thing to be done is to determine the cause of the stains which are so abundant. A satisfactory solution of this question would be of immense practical value, not merely here in the Red River drainage but wherever mussels are found. Different

regions show different degrees of discoloration but stain is present in some degree practically everywhere. How to check it, control it, and eventually eliminate it become exceedingly important questions. This Red River offers ideal opportunities for solving these questions.

2. Practical and efficient fishways should be provided for every dam across a river of the size and importance of the Red River. The blocking of the passage of the fish not only hurts the fishing in the waters above the dam but seriously affects every industry that is at all dependent upon fish. A dam or a natural fall, impassable for fish, may mean the entire absence of mussels in the river above.

3. Until there has been a solution of the cause of the numerous stains on the Red River shells and suitable means have been provided for the passage of the fish around the dams, there is little to be gained either by propagating the mussels already in evidence or by introducing new species.

4. Since the staining is the only character in which these shells are not first quality, since quite a percentage of the shells are free from stains, and since a goodly proportion (unstained part) of most of the stained shells can be utilized for buttons, it follows that a local blank factory, using the shells where they were found would obtain an abundance of material. The loss occasioned by the stained portions of the shell would be more than offset by the saving in freight.

MUSSELS OF THE CROW WING GROUP.

The lakes connected with this group were once part of the great glacial lake Nicollet, which covered 1,500 square miles and drained southwest through the Crow Wing River into the Mississippi. This drainage, therefore, represents the original headwaters of the Mississippi River and was populated with mussels from that source. The center of the Crow Wing drainage is in Wadena County, from whence it extends north through the Fishhook River into Hubbard County and nearly up to the present headwaters of the Mississippi; west through Straight and Shell Rivers into Becker County; west also through Red Eye, Leaf, and Wing Rivers into Ottertail County, and south through Wing and Turtle Rivers into Todd County.

There are very few lakes in this drainage and they are close to the headwaters of the various tributary rivers. Both the lakes and the rivers are shallow, with sand or gravel bottoms; the mussels thus far secured have been obtained with forks and rakes; there was no opportunity to use a crowfoot dredge. The following table gives the distribution of the mussels in this group:

DISTRIBUTION OF MUSSELS IN CROW WING GROUP.

Species.	Stations.			
	Shell River, Menahga.	Leaf River, Wadena.	Fish-Hook River, Park Rapids.	Crow Wing River, Motley.
Lampsilis ligamentina (mucket)	×			×
Lampsilis luteola (fat mucket)	×	×	×	×
Lampsilis ventricosa (pocketbook)	×	×	×	×
Lampsilis recta (black sand-shell)	×			×
Anodonta pepiniana		×		
Anodonta grandis (floater)	×	×	×	
Anodontoides ferussacianus subcylindraceus		×	×	×
Strophitus edentulus (squaw-foot)		×	×	
Strophitus edentulus pavonius (squaw-foot)		×	×	

As can be seen from this table, the mussels are quite evenly as well as universally distributed, and it may be said that they were also fairly abundant at every place examined. Hitherto the mussel fishermen have worked at only one locality in this drainage, the Shell River at Menahga, but the shells obtained here were so exceptional in size and quality that they brought a high price, and many of them were exported to England and Germany.

QUALITY OF SHELLS.

The principal mussel of this drainage is the pocketbook, which attains a large size and has an exceptionally thick shell. It also shows a good luster, has a fine texture, and is free from stains. Consequently it ranks as a first-grade shell and will cut 100 gross of 20-line and 1,000 gross of 16-line buttons to the ton.

The bottom of the river where these shells are obtained is covered with algæ and water weeds to the depth of 12 to 18 inches, and the thicker the vegetation the more plentiful the mussels beneath it. Two men were actively working the Shell River at Twin Lakes near Menahga at the time of our visit, and we watched them rake off the algæ and weeds and then dig into the underlying gravel and sand for the mussels. The latter are often buried to the depth of a foot or more. This is, at the least, a novel condition and one which, so far as is known, has not been reported from any other locality.

The Anodontas were also very thick shelled, so thick as to be easily mistaken for fat muckets, and to cut a poor quality of buttons, Quite a large percentage of the black sand-shells had white nacre. and of course these made first-quality button shells.

PEARLS.

The slugs and small pearls from these shells run about 1½ ounces to the ton of shells, which equals that of the Illinois River, is twice the average for the Cumberland River, and three times that for the Ohio.

An ounce of these pearls and slugs was purchased and they have been carefully examined and compared with those from other localities. In luster and general character they are considerably better than those from the Illinois and Ohio Rivers, but are not equal to the Wabash River output.

One of the musselmen at Menahga showed us a large rosebud cluster of yellowish tint and the size of a small hickory nut, which was attached to the valve of a mucket near the posterior end. They also had several fine pearls, rather more than would be expected from the quantity of shells they had obtained.

While conditions in the Crow Wing and its tributaries are exceptionally fine, as is evidenced by the superior quality of the shells, and while there is an abundance of the right kinds of fish to serve as hosts, these advantages are more than offset by the very poor facilities for transportation.

The rivers run through those portions of Wadena County which are the farthest removed from railroads, and not until we reach Motley in Morrison County do we find good railroad facilities. Even at Menahga the shells must be carted 5 miles over a very sandy road in order to reach a shipping point. The Shell River, however, will furnish gravid pocketbooks of exceptional size and quality to stock other rivers that happen to be more conveniently located.

RECOMMENDATIONS.

1. One of the musselmen at Menahga suggested a way to overcome the lack of transportation facilities. A "wannigan" as he called it—that is, a sort of house boat—could be built and equipped with machinery for sawing blanks at an expense not greatly, if at all, exceeding what it now costs ($300) to transport a single carload of shells from Menahga to the button factories. With this equipment it would be an easy thing to float down the Shell River into the Crow Wing, and down the latter into the Mississippi, using up the shells where they were found. The Crow Wing and its tributaries would supply enough material to keep such an outfit busy for several years. There would be no freight or transportation charges on the shells. Spotted shells, those with thin tips, and the white-nacred sand shells could be utilized along with the others, and when the work was finished the boat and its outfit would bring a very respectable portion of the original cost.

2. While the shipping facilities do not warrant artificial propagation in this drainage, such exceptional shells should not be allowed entirely to disappear before an earnest effort is made to introduce them in other localities. Here is a peculiarly fine parent stock which richly deserves protection and cultivation as a source from whence to derive propagation material.

MUSSELS OF THE MISSISSIPPI GROUP.

As would be expected, this is much the largest of the groups here considered, and includes all of the Mississippi River above the mouth of the Crow Wing River, together with the lakes and tributaries connected with it. This portion of the Mississippi is entirely post-glacial and has been formed since the disappearance of the glacial lake Nicollet.

It drains Crow Wing County, the northern portions of Aitkin, Cass, and Hubbard Counties, and the southern portions of Itasca, Beltrami, and Clearwater Counties. All of these regions, but especially Itasca County, contain a large number of lakes, some of which, like Leech, Winnibigóshish, and Cass Lakes, are among the largest in the State. This region, of course, has been in constant communication with the Mississippi since the very beginning and hence has been stocked with samples of all the mussels found in that river above the Falls of St. Anthony. The following table gives the geographic distribution of these mussels:

DISTRIBUTION OF MUSSELS IN THE MISSISSIPPI GROUP.

Species.	Mississippi River, Brainerd.	Prairie River, Grand Rapids.	Prairie Lake, Grand Rapids.	Mississippi River, Wolf Lake.	Mississippi River, below Bemidji.	Mississippi River, Bemidji Lake.	Mississippi River, above Bemidji.
Lampsilis ligamentina (mucket)	.....	.....	.....	×	×	×	.....
Lampsilia luteola (fat mucket)	×	×	×	×	×	.....	×
Lampsilis ventricosa (pocket-book)	.....	.....	.....	×	×	×	×
Lampsilis recta (black sand shell)	.....	×	.....	×	×	×	×
Anodonta grandis (floater)	.....	×	×	×	.....	×	×
Anodonta corpulenta (floater)	.....	×	×	.....	.....	.....	.....
Anodontoides ferussacianus subcylindracus	.....	.....	×	×	.....	×	×
Symphynota compressa	.....	.....	.....	.....	.....	×	×
Strophitus edentulus (squaw-foot)	.....	.....	.....	.....	.....	×	.....
Strophitus edentulus pavonius (squaw-foot)	.....	.....	.....	×	.....	.....	×

The poverty of specimens at Brainerd is explained by the fact that we could only examine the river for a short distance .above and below the city, and in this interval we did not find any mussel bed. Doubtless there are as many mussels in this portion of the Mississippi as elsewhere.

QUALITY OF SHELLS.

The *Lampsilis* or mucket group are the only mussels in this drainage that possess any commercial value. While the pocketbook does not attain the size or the quality of those found in the Shell River, and the fat mucket is not as thick at those found in Snake River and Pokegama Lake, yet on the whole the shells are of medium size and good quality. They are very plentiful in many places; at the outlet of Lake Bemidji 3 tons were obtained in one week from a space only a few rods in length. These mussels are like those in the Shell River, in that they are buried deep. The man who collected them told us that he dug down into the sandy bottom 2 and 3 feet for them and found them nearly as thick as they could lie.

The shells were remarkable for the small size of the cardinal teeth, indeed a few valves were found entirely destitute of teeth.

Another excellent locality is up the Mississippi above Lake Irving. The conditions here are excellent and several carloads of shells could easily be obtained. The Schoolcraft River comes into the Mississippi here from Lakes Marquette and Plantagenet and both the river and the lakes are reported to be full of good mussels.

The black sand-shells throughout this portion of the Mississippi have the hinge margin very strongly curved like those already described from the Red River and the Crow Wing drainage.

The fat muckets here are not thickened like the shells from Pokegama Lake, Pine County, and many of them are dwarfed after the manner of ordinary lake shells. In addition, those from Wolf Lake proved to be chalky and brittle when tested for button making, but those above Lake Bemidji were of medium size and furnished good button material.

The Anodontas form but a very small percentage of the mussel fauna, nearly all the shells seen being some form of *Lampsilis*. The mussels in this region would all be obtained with a fork or a rake; there is no locality where the water is deep enough to use a crowfoot dredge.

PEARLS.

Quite a number of pearls and slugs have been obtained by professional pearlers, especially in the region about Bemidji. One beautifully colored pearl as large as a hazelnut had been purchased by a firm of jewelers in Bemidji just before our arrival there and was valued at $200. It weighed 21 grains, but had a slight blemish on one side. Some pearling has also been done in the Mississippi below the power dam, which is situated 11 miles down the river from Lake Bemidji. One pearl found here in July, 1912, was valued at $300. There was also a display of pearls and slugs and manufactured

articles in the window of this jewelry store, all of which were stated to have been found in the vicinity. We saw several piles of shells that had been recently made by pearlers along the stretch of river above Bemidji, but did not find them anywhere else in this drainage. Evidently there has been very little search for pearls anywhere within this entire drainage.

PROPAGATION.

The conditions in most of the lakes and rivers of this group are excellent for propagation purposes. The water everywhere is clear and contains an abundance of lime; the bottom is almost universally composed of hard sand and gravel; there is nowhere any surfeit of algæ or aquatic vegetation, and there is apparently an abundance of food.

At Leech Lake, which, next to Red Lake, is the largest body of fresh water in the State, the outlet is muddy and full of weeds, and is reported to contain nothing but very thin-shelled floaters or paper shells. But the lake itself presents ideal conditions, and a small river which runs into it on the south shore out of Lake Linda is reported by a mussel fisherman to be full of thick shells for the mile of its course. The same fisherman said that Little Bay River, which enters the lake on the west shore, contains no commercial mussels from Leech Lake up to Laura Lake, but from there up to Little Bay Lake is full of them.

Lake Winnibigoshish was formerly a shallow mud lake, but its surface was raised 14 feet by a dam across the outlet. It would furnish a favorable locality for the introduction of the three-ridge, blue-point, washboard, and similar mud-loving species.

Cass Lake, Long Lake, and Wolf Lake are also very favorably situated, and all three, as well as the intervening portions of the Mississippi River which connects them, contain good bottom material. The conditions here are similar to those on the Snake River in the St. Croix drainage, and would be particularly well suited to the thick-shelled fat muckets.

The Mississippi flows through Lake Bemidji and Irving Lake to Beltrami County, and here again the conditions appear very propitious for the propagation of the fat muckets.

At Pokegama Lake in Itasca County there are long stretches of sandy beaches and numerous sand bars, which, combined with something of a current flowing through the lake, would favor the introduction of the yellow or slough sand-shells. This lake is 14 miles in length, but is quite narrow, and is made up of a succession of long arms and bays surrounded by fairly high land. A dam was placed across the outlet about 8 years ago, which raised the water in the lake 10 feet, and which effectually prevents any fish from entering the lake out of the Mississippi River.

At Prairie Lake, 6 miles north of Grand Rapids, the water is considerably discolored with iron brought down by the Prairie River from the Mesabi Iron Range. This iron does not appear to affect the mussel fauna at all, since they are neither stunted nor discolored. But thousands of logs are run down the Prairie River, and the bottom of both the river and much of the lake is covered so thickly with fragments of bark that no mussel can live in it.

It is hardly necessary to add that all these lakes, the Mississippi itself, and its tributaries are full of just the right kind of fish to serve as hosts. Furthermore, Walker, Cass Lake, Bemidji, and Grand Rapids are very conveniently situated for propagation work, and are in easy railroad communication with all other parts of the State.

RECOMMENDATIONS.

1. As noted under the Red River group, suitable passage should be provided for fish around the dams at the outlet of Lakes Pokegama and Winnibigoshish, and the large power dam 11 miles below Lake Bemidji. These last two are across the Mississippi, and surely that river ought never to be closed to the passage of fish, to say nothing about the mussels.

2. The farther the source of supply is removed from the button factory the greater is the cost of transporting the shells. Therefore, in a city like Bemidji, forming a convenient center, the establishment of a local factory for sawing blanks can not be too strongly recommended.

3. This is not the best locality for trying the experiment of introducing commercial species of mussels into some of the Minnesota lakes. But after such an experiment has been made a thorough success, there are large and well adapted lakes here in which artificial propagation would undoubtedly yield profitable returns.

MUSSELS OF THE ISOLATED LAKES.

LAKE PEPIN.

This so-called lake is really a simple widening of the Mississippi River just below Red Wing. The bottom is of fairly coarse gravel mixed with some mud, there is very little current, and the water varies from 6 or 8 to 12 or 15 feet in depth. This locality has not been fished for mussels until within a few years, but at the time of our visit there were 100 clamming outfits along the east shore of the lake, and they were averaging more than 200 pounds apiece per day.

An examination of the piles of shells collected by these fishermen yielded examples of the following species: *Lampsilis luteola, recta, fallaciosa,* and *alata, Unio gibbosus, Strophitus edentulus, Obovaria reflexa,* and *Quadrula plicata, undulata,* and *pustulosa.*

The culls were mostly razorbacks, spikes, such of the black sand shells as have a pink nacre, and a few floaters. By count about half of the commercial shells obtained are fat muckets (*luteola*), while by weight they form only 40 per cent of the entire catch.

A large number of fine pearls have been found here, nearly all of which come from the *luteolas*. One of these found just before our visit sold for $300, and another for $150. The fishermen reported the pearls not as numerous as during the previous year. They also reported another curious fact, that shells with pearls run along certain ridges on the lake bottom and are not found in the hollows along either side of the ridge.

In view of these facts it would seem advisable to propagate artificially the local commercial species, especially these thick-shelled *luteolas*, and to use this locality as a source from which to introduce desirable species into other lakes and rivers.

Mr. Andy Noel, a shell buyer for the Wisconsin Button Co. at La Crosse, took us around the lake and showed us every courtesy in the way of obtaining samples and data. Our sincere thanks are hereby acknowledged for these kind attentions.

PLEASANT AND CLEARWATER LAKES.

These lakes are situated near Annandale, in Wright County, and are connected by the Clearwater River with the Mississippi. Pleasant Lake, right in the edge of the town, is $2\frac{1}{2}$ miles long and 1 mile wide, with a gravelly and sandy bottom, comparatively free from vegetation. Shells of the pocketbook (*ventricosa*) and *Anodonta pepiniana* were obtained here. The former proved to be excellent button material, but was very scarce. It was reported, however, to have been abundant during the previous year, but had been killed or driven into deeper water by the ice.

Clearwater Lake is 4 miles from town and is much larger than Pleasant Lake, being $7\frac{1}{2}$ miles long and $1\frac{1}{2}$ miles wide. The southeastern end of the lake is wider and deeper and has rocky shores; the northwestern half is narrower, shallower, and so lined with reeds and rushes that it is impossible to get anywhere near the shore in most places.

The fat mucket (*luteola*) was found here, in addition to the pocketbook and *A. pepiniana*. Both the mucket and the pocketbook are large and thick and make excellent button material.

The Clearwater River flows through the lake and was reported to be full of fine shells. This lake and river would yield a carload of first grade mussels, which could be readily floated down to the town of Clearwater, on the bank of the Mississippi, and shipped from there. Also the local species might well be propagated at the lower end of the lake and in the river, while in the muddier bottom at the

upper end of the lake it is probable that some of the pig-toes (*Quadrula*) would thrive well.

It is very doubtful whether any recommendations can be made for Pleasant Lake.

PULASKI, BUFFALO, RICE, AND KORONIS LAKES.

These four lakes are connected with the Crow River, but the outlets are very small streams, and those of the first two are open only during spring freshets.

Lake Pulaski is nearly circular in outline, about $1\frac{1}{2}$ miles in diameter, with a bottom composed of gravel and sand, covered with a heavy growth of *Chara*, *Potomageton*, and algæ.

Buffalo Lake is $2\frac{1}{2}$ miles long and 1 mile wide, with a maximum depth of 50 to 60 feet. There are two shallow bars across the center of the lake which are covered with rushes, and the bottom is firm sand and gravel, with very little vegetation.

Rice Lake, 6 miles northeast of Paynesville in Stearns County, is 3 miles long by 2 miles wide. The bottom is composed of much coarser gravel than in Buffalo Lake, and there is a little more *Chara* and algæ. The north fork of the Crow River runs into the southwest corner of this lake and empties out again within a short distance.

Koronis Lake, 2 miles southeast of Paynesville, is $3\frac{1}{2}$ miles long and 2 miles wide, with a very irregular and precipitous shore. The bottom contains much more sand than gravel and the vegetation is very limited except at the inlet and outlet.

The fat mucket (*luteola*) and *Anodonta pepiniana* were found in all four lakes, and in addition *Anodontoides ferussacianus modestus* was found in Buffalo and Koronis Lakes. Most of these muckets are dwarfed, as is usual in a lake, and thin-shelled, but those from Rice Lake are full size, of good thickness and have a fair luster, and were classed as first-grade shells.

The *Anodontas* were found in regular windrows 10 or 15 feet from shore, and outside of them were the *luteolas*, in water shallow enough to obtain them by wading. The epidermis of these *luteolas* was a dark straw-yellow, and was highly polished like that of the same species from Lake Henry (p. 11).

The comparative paucity of shells in these lakes is easily explained by the fact that fish can not run into them freely at the time of year when they are infested with glochidia. The conditions in Buffalo Lake are excellent for sand-shells and species which frequent shallow bars. The thick-shelled *luteolas* from Pokegama Lake (Pine County), or Lake Pepin would undoubtedly thrive in Rice and Koronis Lakes. Lake Pulaski is not worth stocking with any kind of shells.

Each of these lakes contains an abundance of perch, bass, sunfish, crappies, and wall-eyed pike, which could be seined with little trouble

and would furnish sufficient hosts for the glochidia; therefore, in case the artificial stocking of lakes proves a success, three of these lakes present good opportunities for work on commercial species.

SAUK LAKE AND SAUK RIVER.

Sauk Lake, 3 miles above Sauk Center in Stearns County, is 7 miles long and $\frac{3}{4}$ mile wide, and is thus little more than a widening of the river. It is partly natural and partly artificial, produced by a dam across the river at Sauk Center. The bottom is composed of sand and coarse gravel, covered with a profuse growth of algæ, *Chara*, *Potomageton*, and other aquatic vegetation. The only mussels found in the lake were the fat mucket (*luteola*), *Anodontoides ferussacianus modestus* and *Anodonta pepiniana*. The muckets are thin-shelled, dwarfed, and covered with a large amount of marl posteriorly. The epidermis is honey-yellow in color, highly polished, and faintly rayed. The two floaters, of course, possess no commercial value, and were found only in limited numbers.

The river was examined below the mill dam at Sauk Center, and again 3 miles above St. Cloud. The fat mucket (*luteola*), the pocketbook (*ventricosa*), and the black sand-shell (*recta*) were found in abundance at both places, and in addition near St. Cloud there were some ordinary muckets (*ligamentina*) and Anodontoides.

The fat muckets were of river size, and a small percentage were thick enough for buttons, the ordinary muckets were of large size and thick-shelled, but were somewhat spotted; the pocketbooks were exceptionally large, much flatter than usual, thick, and with a good luster, but they were also spotted, and on being tested proved to be brittle, thus rendering practically worthless material that to all appearance seemed to be as good as that from the Shell River at Menahga. The only thing worthy of comment here is the lack of a suitable fishway around the dam at Sauk Center. The effect of this is seen in the fact that although the pocketbook was common just below the dam, not one could be found in the 3 miles of river above the dam.

LAKE MINNEWASKA, LAKE OSAKIS, AND BATTLE LAKE.

Lake Minnewaska, situated at Glenwood, near the center of Pope County, is 8 miles long and 2 miles wide. The bottom is of sand and rather fine gravel, with numerous shallow sand bars along the southwestern shore. The average depth of the water is from 12 to 15 feet, and while there is an interrupted fringe of rushes along the shore line the lake itself is exceptionally clear and free from aquatic vegetation. There is no outlet except during very high water, when a small stream overflows into the Chippewa River, which is a tributary of the Minnesota River.

The lake is fed by numerous large springs in addition to several inlet streams, which drain the surrounding country. The lake contains an abundance of sunfish, perch, crappies, wall-eyes, and bass. On the northwest shore of the lake, within the city limits of Glenwood, there is a State fish hatchery under the supervision of Supt. J. A. Pinkerton. The water for the hatchery comes from one of the large springs that feed the lake, while a series of fishponds or aquaria are built in the lake along the shore. The lake was found to contain a great many mussels, which, however, possess no commercial value. These include the fat mucket (*luteola*), which is much dwarfed and thin-shelled, with an epidermis which erodes easily and turns dead white on exposure, three species of *Anodonta*, *imbecillis*, *pepiniana*, and *benedictensis*, and *Anodontoides*. The profusion of these mussels and the rapidity of their development show that there is an abundance of food in the lake.

We find, therefore, that the temperature and depth of the water, the kind of bottom, the presence of numerous shallow sand bars, the freedom from aquatic vegetation, and the abundance of suitable food combine to make this lake an ideal one for the artificial propagation of mussels, particularly the *Lampsilis* group. And, as if to complete the requisites, here is a fish hatchery, in whose interests hundreds of bass and wall-eyes are seined out of the lake every spring. Along with the game fish which are used by the hatchery there are always taken in the seine a large number of sunfish and yellow perch which are simply thrown back into the lake. What could be simpler than to supply the hatchery with gravid mussels of some valuable commercial species and impregnate these sunfish and perch with the glochidia before they are returned to the lake? Manifestly this is a rare opportunity for testing the possibilities of mussel propagation with almost no additional expense. The importance of such practical experimentation under the direction of skilled workmen can hardly be overestimated.

While in Glenwood we were rendered great assistance and were shown many courtesies by the officials at the hatchery. One of them, Mr. John Dahl, took us around the lake, gave us many data, and explained the local conditions, with which he was thoroughly conversant. Our sincere thanks are hereby returned to him and to the superintendent for these and many other favors.

Lake Osakis, situated close to Osakis, in the southwestern corner of Todd County, is 10 miles long and 3 miles wide. The bottom, the depth of the water, the presence of sand bars, and the freedom from aquatic vegetation correspond exactly to those at Lake Minnewaska. This lake also has no outlet except at very high water, and is a typical shallow lake, such as are common in glaciated regions.

There were found here the fat mucket (*luteola*), *Anodonta pepiniana* and *Anodontoides*. Some of the muckets were dwarfed and thin-shelled, but a small percentage were full-size and had moderately thick shells.

Battle Lake is in the southern central portion of Ottertail County and empties into the Red River. It is 6 miles long by 3 miles wide. It has a bottom of sand and gravel sparsely covered with aquatic vegetation, and the water is very clear and cold. The fat muckets here were small and dwarfed and approached very closely the species known as *rosacea*. They were easily eroded, and the epidermis on exposed portions of the shell became absolutely snow-white.

In addition there were two species of *Anodonta*, viz, *pepiniana* and *kennicotti*, and *Anodontoides*. All of these shells, including the muckets, were worthless from a commercial standpoint.

Neither Battle Lake nor Lake Osakis has a fish hatchery, but otherwise they possess as favorable conditions as those at Lake Minnewaska, and are as conveniently situated. Consequently, if the experiments at Lake Minnewaska proved successful, it would be an easy matter to repeat them in these two lakes.

SUMMARY.

1. Fat muckets (*Lampsilis luteola*) with exceptionally thick shells, and making first-grade button material, are plentiful in Pokegama and Cross Lakes, and in the Snake River, and also in Lake Pepin. They are not found in any of the other lakes or rivers which were examined.

2. Pocketbooks (*L. ventricosa*) of unusual size and luster are abundant in the Shell River and Twin Lakes near Menahga and elsewhere throughout the Crow Wing drainage and in the Sauk River. The Crow Wing shells are of superior quality and command a high price. Those from the Sauk River are so brittle as to render them worthless.

3. Muckets (*L. ligamentina*) are common in the Crow Wing and its tributaries and in the upper Mississippi. They are the ordinary good button material that is common in this species.

4. Black sand-shells (*L. recta*) are fairly abundant in all the rivers visited. Nearly all have purple nacre, are very thick, and make excellent material for novelties. The only exceptions are the white-nacred ones found at Menahga, which are excellent button shells.

5. Pig-toes (*Quadrula*) are found only in the St. Croix drainage and in the Red River. There are none in the Mississippi above the Falls of St. Anthony, nor in any of the other rivers and lakes visited. Some of the three-ridges were badly spotted, but all of the other pig-toes were of first quality and would make good button material.

6. Bemidji, in Beltrami County, is the best center from which to work the upper Mississippi. A blank factory situated there could

easily find material to keep it running for several years. Phelps, in Ottertail County, would make an equally good center for the Red River.

7. There are two of the recommendations which possess especial importance: First, to preserve by artificial propagation the types of shells shown in the muckets of Lake Pokegama and the pocketbooks of Menahga; second, to improve the opportunity so favorably offered at Lake Minnewaska and thoroughly try out by experiment the introduction of valuable commercial species into lakes that are specially suited to them.

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MANITOBA

ONTARIO

LAKE SUPERIOR

the North

Rainy River

RED LAKE

Red River of the NORTH

BEMIDJI LAKE

Bemidji

Cass Lake

LAKE WINNIBIGOSHISH

LAKE ITASCA

LEECH LAKE

Walker

Grand Rapids

Prairie River

Park Rapids

Crow Wing River

Menahga

LITTLE PINE LAKE

Perham

OTTERTAIL LAKE

Wadena

Fergus Falls

BATTLE LAKE

Motley

Brainerd

MILLE LACS

Snake River

POKEGAMA LAKE

Pine City

St. Louis River

Duluth

Carlton

LAKE SUPERIOR

LAKE OSAKIS

Alexandria

Osakis

Sauk Centre

LAKE MINNEWASKA

Glenwood

Paynesville

Sauk River

St. Cloud

Mississippi

LAKE KORONIS

Annandale

Minneapolis

St. Paul

St. Croix River

TRAVERSE LAKE

BIG STONE LAKE

Minnesota River

Red Wing

Lake City

LAKE PEPIN

Winona

Homer

SOUTH DAKOTA

IOWA

WISCONSIN

NOTE

Primary Water Sheds

Line of Travel

Stations

Scale

10 5 0 10 20 30 40 50

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